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ISSUES IN SOFTWARE MAINTENANCE

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ABSTRACT

Up to a few years ago the area of software maintenance was largely ignored. Interest has increased in the last few years due to several factors. First, the increased volume of enhancement and maintenance with more systems from that of ten years ago has restricted resources available for new development. Second, there has been a growing awareness that tools and aids which assist development of information systems may have little effect on operational systems. Third, the management of information systems has come under increasing scrutiny.

In this paper we highlight some of the major issues that surfaced during several extensive operational software studies. These sources have pointed to significant questions that must be addressed concerning the roles of the users in operations and maintenance, the management of maintenance, and the types of tools and techniques that are needed in maintenance.



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1. INTRODUCTION

During the past four years an effort has been made to develop a better understanding of software maintenance and enhancement in particular and operational software in general. Several factors motivated this attention. First, it has been widely observed that software maintenance and operational support consume substantial resources in the information systems environment. Although personnel consumption is the most frequently emphasized, hardware and system software are also consumed. Multiple versions of data communications monitors and operating systems are often needed to keep older systems running. This is due to the inability of the application software to migrate to newer releases of systems software.

A second factor is the resource issue in general. Personnel availability is limited. Turnover of systems staff is a major concern for many organizations (over 30% per year in some organizations). In the area of operational software turnover of maintenance personnel can result in reduced support of the application system and even result in damage as untrained or unfamiliar staff attempt to grapple with a particular enhancement or maintenance fix.

A third factor is the sense that much of the software engineering and computer science research has not touched on the problems associated with maintenance and operations. Research has produced many development tools and techniques. Some of these have substantial merit. However, these tools are not easily transferred into a maintenance environment involving large scale operational applications which are over five years old. There is not enough resources to rewrite the software using the new tools.

2. RESEARCH METHODS

The research program began with a small scale survey of less than one hundred systems. The results were reported in LIET78. The survey was based on a fifteen page questionnaire mailed to firms in the western United States. Several interesting results emerged from the survey. First, maintenance and enhancement were found to consume approximately half of the systems and programming personnel hours. Approximately 60% of the effort was in the area of perfective maintenance (i.e., system enhancements, improved documentation, and recoding for efficiency). This finding was somewhat unexpected since the literature had supported the belief that fixing programs and keeping systems operational were the major concerns. A third finding was that problems of a managerial nature were viewed as more significant than those of a technical type.

An applied research program was initiated to determine what studies and analyses had been carried out. A literature search proved somewhat disheartening. With few exceptions the meager literature was based on extremely small sample sizes. From such limited data very substantial conclusions were drawn. Some of these in retrospect are worth reviewing. There is the hypothesis that maintenance burdens continue to grow unabated. There is the feeling that staff morale and motivation in maintenance are very low. A third hypothesis was that development tools could be used to reduce maintenance costs. Overall the hypotheses centered on the technical aspects of maintenance. The reader is referred to the papers BELL76, BOEH75, BOEI76 and CANN72 for some of the more interesting findings.

Interest in maintenance was also increased as a result of this study. Individuals contacted during the survey continued to pursue analysis. Several

organizations adopted changes suggested as a result of the research. These factors and the small sample size encouraged a larger sample size survey.

A larger survey consisted of a sample of two thousand management members of the Data Processing Management Association (DPMA). This organization was selected because it has the largest percentage of membership based in systems personnel in industrial positions. The survey methodology and results are contained in the book LIES80. Summary results and other findings have been presented in LIES78, LIES82. For background it is useful to highlight the methodology employed in this larger sample.

The DPMA Foundation provided a randomly generated subset of the ten thousand members who classify their jobs in management. The questionnaire was accompanied by an endorsement letter by the DPMA Foundation. Return envelopes and followup postcards were used to encourage response. There were 486 valid responses. This is quite remarkable considering that the questionnaire was lengthy (over 17 pages) and conducted by mail. The data was entered into a computer and analyzed using the statistical routines in SPSS. Some of the major issues that surfaced are discussed in the next section.

These surveys were conducted with a base consisting mainly of business systems as opposed to real time, sensor based systems. With factory automation, improvements in command and control, and increased on-line systems it was felt that the methodology should be applied to this group of systems.

In 1980 a limited study was undertaken for the Office of the Assistant Secretary of the Navy of eighteen weapon systems by P. Wegner and the author (LIEW81). Each software weapon system is in operational use for a particular Navy airplane, missile, or ship class. Most of these systems were real time, fed by sensors and/or radar. The results of this study confirmed the findings of the larger previous study.

The questionnaires used in the surveys were divided into two parts. One part focused on the organization and how maintenance was carried out in general. The second part centered on an application. The application system selected by the respondent had to satisfy three criteria: (1) the system must have been in operation at least one year; (2) there must be significant maintenance work attached to the system; (3) the system must be of major importance to the organization.

To identify issues from the data several methods were employed. At the end of the questionnaire was a list of problem factors that have been mentioned in the literature or inferred in previous versions of the questionnaire. This list of problems grew from twenty in the first version to over thirty in the latest version. The thirty areas included management and user oriented as well as technical issues.

In the next section we summarize the issues and problems that have been discovered in the areas of application software maintenance and operation. Section 3 presents a possible framework or an approach and suggests specific areas where further work is needed.

To assess quality of response for many questions which asked for quantitative answers respondents were asked to assess the quality of the response (reasonably accurate, based on good data; rough estimate, based on numeral data; best guess, not based on any data). This is a measure of the knowledge about the system in a snapshot mode.

A question was also asked about controls in place in the system. These were for controls regularly employed and in place. Included here were such controls as logging request, cost justification of change, trouble logging, formal audit, and charge back of costs (equipment and personnel). The later survey added specific controls for Defense Department Standards.

Beyond these direct methods of identifying issues and how systems were measured and controlled, there are also a number of indirect measures based on other data. For example the size aspects of the system were asked for current and for one or two previous years. This revealed an interesting longitudinal view of maintenance.

It is also possible to interpret and extract issues from the number of people who work on the system, the number who worked on the system in development and are still working with it in maintenance, and the percentage of effort in various maintenance and enhancement tasks.

3. ISSUES AND PROBLEMS IN APPLICATION SOFTWARE MAINTENANCE

In the surveys five areas of issues have emerged as dominant and comprehensive. We will consider each of these in terms of research as well as implementation concerns.

3.1 Conceptual Issues

At the heart of maintenance is its very definition. In the surveys an inclusive definition was employed. Such a definition includes enhancements and operational support as part of maintenance along with routine debugging and problem identification and resolution. More specifically, the questionnaires in the larger commercial survey and weapons survey included as maintenance emergency fixes, routine debugging, accommodations of changes in file/data input, accommodation to hardware/software change, enhancements, documentation improvement, and recoding for efficiency. Enhancements were divided into new reports, adding data, reformatting, consolidation, file expansion and condensation of data. There are psychological impacts based on a

possible derogatory implication of the work maintenance. However, the inclusionary definition helps to aggregate the support needed for an operational application system. The research has shown in all three studies that enhancements for users are the major activity (50-70% of the total of maintenance and enhancement). Adaptation to new technology surfaced only in the weapons systems survey as a major activity. Emergency fixes and recoding for efficiency were relatively minor in resource utilization (less than 20%) as was documentation (less than 5%).

Associated with the definition of maintenance is the extensive continued development of an application system. For many systems there appears to be no single life cycle. Rather the life cycle appears to repeat itself. The data appeared to support the view that once development was complete and the system stabilized in operational use, enhancements began individually or in groups (indicated by the snapshot of two time periods (present and one year prior) in the questionnaire. The data indicated that while total maintenance in the organization is approximately the same as development, maintenance on particular systems declined as the initial operational errors were fixed and then increased as users requested enhancements. The author has worked with a number of systems projects and groups and has seen this first hand. Belady also refers to it in systems software. However, the data was not sufficient to fully support this hypothesis. If the hypothesis holds for a particular system, then as users request new enhancements, a new developmental cycle is begun.

What is needed in the conceptual framework of maintenance is a complete classification of the tasks and work done under the maintenance umbrella. SWAN76 has begun this work. It needs to be further refined. While the concept of maintenance appears academic, there are substantial practical implications as well. A classification method could be used to assist project

control systems. The classification into perfective, adaptive, and corrective maintenance is now in use in a number of organizations and has proved beneficial in cost estimation by task and type of system. Systems groups increasingly are charging back their costs to user organizations. A necessary part of the foundation is fairly accurate estimation of costs. The data and classification method assist in this task.

3.2 Measurement Issues

Beyond maintenance is the issue of how to measure a system. We are not concerned here with systems measurement in general. Rather we are concerned with measurement during maintenance itself. The surveys indicated that systems with very similar sizes revealed entirely different patterns of maintenance activity. The findings of the surveys shed light on an expanded measurement approach. The findings revealed the key role of the user and manager in maintenance activities. This suggests that measurement of software should be done externally as well as internally.

To explore change sources it is useful to consider the environment of an application system. There are four basic parts of the environment which can affect a system.

- User external

This environment includes legislation, competitive pressures, social and cultural factors. It also includes the internal user organization and staffing. There are quantitative factors here which can be gathered. The requests for change can be classified as to their ultimate source. The number of users actively working with the system can be measured. It is clear from the data processing surveys that this area has been overlooked.

- Technological

Technological change can affect applications. Distributed data processing can result in the split of an application across multiple computer systems. New, more intelligent terminals may have the same impact. Technology may also make it possible to join or tie together separate applications.

- Managerial

Management pressure is frequently exerted to control costs and to modify schedules. This pressure can directly impact the maintenance effort and its quality. It is one reason why documentation of changes is frequently not done or is insufficient. Managerial pressure also focuses on the short term. There is a lack of attention to fundamental rework of application systems using new techniques. Who wants to expend the effort to rework something that works? This in turn prevents the use of productivity aids. System size gets larger as enhancement piles upon enhancement. The surveys reveal, not unexpectedly, that systems become more complex and difficult to maintain as they age. They grow in size and complexity. The original staff that know the application attrition out of the organization.

- Marketplace

The marketplace produces new products and services as we have noted in technology. It also creates a competition for personnel, exerting more pressure on the maintenance staff. Furthermore, new products and services may spur the users to request more enhancements.

3.3 Scale of Effort

The contention in the past has been that the percentage in maintenance is steadily increasing. The surveys do not bear this out. The data indicates

that the percentage is relatively stable in most organizations - about 50% of the effort. However, there are organizations in the samples which report sharply rising percentages over a two year period. The respondents in several instances indicated that controls are exerted by management to reduce the percentage. Thus, it appears that scale of effort is heavily dependent on the organizational environment and the portfolio of application systems being developed and maintained at a given time.

3.4 Organizational Issues

In the past interest has centered on the organization of maintenance within a systems group. Questions that arise are whether it should be separated or combined with development. However, given the rising interest and impact of the user community it might be well to consider more global issues. What is the role of the users in maintenance and enhancement? Should users be given report generators and other aids? Should users be responsible for production? After all this is true today in a number of minicomputer based on-line systems.

The role of users is a major issue for systems groups in general. Nationally there is a shortage of 20-30% in systems personnel. Users may have a role in filling the gap between supply and demand. This is happening today in many organizations and likely to continue as delays lengthen due to staff shortages. Thus, the user role in maintenance, enhancement, and operations needs to be assessed in general.

A separate, but related organizational issue is that of controls for the system. The surveys in the commercial sector reveal that many controls that are supported in education and theory are not used in practice. The issue here is the trade-off between the benefits of the controls and the cost of their control and implementation. Also, many organizations lack the technical

implementation aids that make such controls bearable. The issue here is to determine which groups of controls are appropriate to each category of application systems.

3.5 Productivity Issues

A main research focus has been the productivity of programmers and to a lesser extent analysts in the systems organization. A variety of techniques have been devised. The surveys reveal only limited use. Furthermore, in cases where they are employed the results from the survey are not significantly different from traditional methods. It should be emphasized that there was no control or verification of the techniques among the respondents.

But is the productivity of programmers the major concern? The findings cited in the survey results and what we already discussed point to the user and manager areas. There are far more users than developers or maintainers. Thus, if a productivity technique can be found for a user function, its effect is multiplied far more than that for programmers. This also relates to the role of the user that was discussed earlier. Productivity of users which are performing less complex tasks may be easier to achieve than aiding a programmer with a complex task.

A second area of productivity tools has focused on the analysis and design stages of system development and enhancement. These tools aim at improving the design correctness and completeness. The thought here is that by nailing down the requirements, the system will be easier to maintain and will more completely meet the user needs. This view of the world was probably valid at a time when systems were batch oriented and when users were not involved with systems. Today the situation is changed. User management pressures users to automate to control user organization costs. Requirements which in the past were more stable are so no longer. In many areas there are

substantial changes each year that result in major enhancements and retrofitting.

4. Perceived Problem Areas

The major surveys provided respondents with 26 potential problem areas in maintenance. The respondents were asked to rank these on a scale of 1 (no problem) to 5 (major problem). A variety of problem areas were listed and are summarized in Figure 1. The six problems seen as most severe were:

- Quality of application system documentation.
- User demand for enhancements and extensions.
- Competing demands for maintenance programmer personnel time.
- Meeting scheduled commitments.
- Turnover in user organization.

Of the six problems seen as most severe, three are concerned with users, two with the management function of apportioning resources, and one (documentation) with a technical issue -- albeit not one relating to programming. The predominance of non-technical issues is striking.

Statistical analysis uncovered six main groupings of problem areas:

- User knowledge (11, 25)
- Programmer effectiveness (16, 14, 5)
- Product quality (22, 6, 2)
- Programmer time availability (8)
- Machine requirements (12, 13)
- System reliability (17, 18)

Components are given in Table 1.

Additional statistical factor analysis was performed to determine which factors contributed to the variance. The ranking was as that given above with

FIGURE 1: POTENTIAL PROBLEM FACTORS IN MAINTENANCE SURVEYS

	Ranking (Large Commercial Sample)	Ranking (Weapons Systems)
1. Maintenance personnel turnover-----	14	5
2. Documentation quality-----	3	8
3. System hardware and software changes-----	17	19
4. Demand for enhancements and extensions----	1	1
5. Skills of maintenance programmers-----	16	18
6. Quality of original programming-----	7	4
7. Number of maintenance programmers available-----	8	6
8. Competing demands for programmer time-----	2	17
9. Lack of user interest-----	23	
10. System run failures-----	24	16
11. Lack of user understanding-----	6	26
12. Program storage requirements-----	19	3
13. Program processing time requirements-----	9	2
14. Maintenance programmer motivation-----	21	15
15. Forecasting maintenance programming requirements-----	11	12
16. Maintenance programming productivity-----	18	24
17. System hardware and software reliability---	26	10
18. Data integrity-----	22	25
19. Unrealistic user expectations-----	10	23
20. Adherence to programming standards-----	15	11
21. Management support-----	25	22
22. Adequacy of system design specifications---	12	9
23. Budgetary pressures-----	20	20
24. Meeting scheduled commitments-----	5	7
25. Inadequate user training-----	4	13
26. Turnover in user organizations-----	13	21

user knowledge as the major component at 59.5% followed by programmer effectiveness at 11.9%. User knowledge includes user training and user expectation for changes as well as a lack of user understanding. Programming effectiveness includes skills of programmers as well as their productivity. In the surveys several potential problem areas which have been widely mentioned as concerns in the literature failed to be significant. These included processing and storage requirements, data integrity and hardware/software reliability. Migration across to new generations of hardware was not viewed as significant. This is partially because the manufacturers often provide software to aid such migration.

Some interesting observations appear from the data for this question. Of the top three problems only one (documentation quality) emerges as more than a minor problem in the technical area. The largest problem in ranking is user demand. Second is competing demand for personnel time. This relates to the role of users in maintenance and enhancement. If users were involved in more activities their understanding would improve, perhaps, impacting demand. In many organizations a small number of people are significant resources for a range of systems and tasks - making competition for their time more intense.

Of the top sixteen items (that which ranked above 2 on the scale of 1 to 5) six are management oriented, five are user oriented, and five are technical. Of the remaining ten all but two are technical.

In the same figure are the rankings for the military systems. These systems largely depend on hardware which is older and limited in capabilities. This accounts for the significance given to technical hardware and software issues. A hypothesis is that data for many on-line systems which are at the hub of the business organization (e.g., demand deposit, on-line reservations) would probably be similar. User issues include testing due to the limited constraints within which the application software must function.

Personnel turnover impact was viewed as significant when turnover occurred. This is due to the correlation found between the experience and time spent with the application system being inversely related to the degree to which maintenance of the system was perceived to be a problem. Maintenance effort was also found to negatively correlate with the time spent with the system.

With these problem areas highlighted we can turn again to the productivity aids. Most of the aids that have been developed to date (e.g., structured programming, HIPO, structured walk-through, etc.) have limited impact. In LIE580 and LIEW81 the use of tools such as structured programming, design, test tools, automated documentation, and other tools was assessed. The results indicated that no tool was used in over 30% of either survey. Furthermore the use or non-use of tools had little impact on the total amount of maintenance and enhancement except to slightly increase resources for enhancements. The problem with tools is that it is too expensive and costly to retrofit the system to take advantage of the tools. Further, many tools appear to gain and then dim in acceptance. Yet application system maintenance must continue sometimes long after the software tool or methodology technique has dropped from favor.

5. CONCLUSIONS

While much more research is needed in maintenance, the work thus far indicates that in the future consideration will need to be given to maintenance in the user area as well as systems. Application systems maintenance will continue as an area of concern, but will be more focused on substantial enhancement and maintenance. Table 2 indicates some of the activities of user, operations, and system responsibility.

Since we are just now involving users on a larger scale, we have the opportunity to organize and control or coordinate user activities. Figure 1 shows some of the user report activities. The need for user operated and managed tools, techniques, and aids will grow. These responsibilities are likely to be more structured than informal decision support systems since they will be exercised in conjunction with routine data processing and everyday business enterprises. Some of the issues in user maintenance that may arise are: documentation, interfaces to base system (maintained by systems), use of microcomputer software with base system data, data quality, retention and recovery, user productivity, verification and testing, and technology transfer. Thus, a dual maintenance framework may emerge: one for the base systems emphasizing efficiency and control, perhaps, and one for user maintained functions and systems supporting effectiveness and goodness of fit to ^{current} ~~current~~ organizational needs.

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TABLE 1
PROBLEM FACTORS AND THEIR COMPONENTS

User knowledge.

- Lack of user understanding of application system.
- Inadequate training of use personnel.

Programmer effectiveness.

- Maintenance programming productivity.
- Motivation of maintenance programming personnel.
- Skills of maintenance programming personnel.

Product quality.

- Adequacy of application system design specifications.
- Quality of original programming of application system.
- Quality of application system documentation.

Programmer time availability.

- Competing demands for maintenance programming personnel time.

Machine requirements.

- Storage requirements of application systems programs.
- Processing time requirements of application system programs.

System reliability.

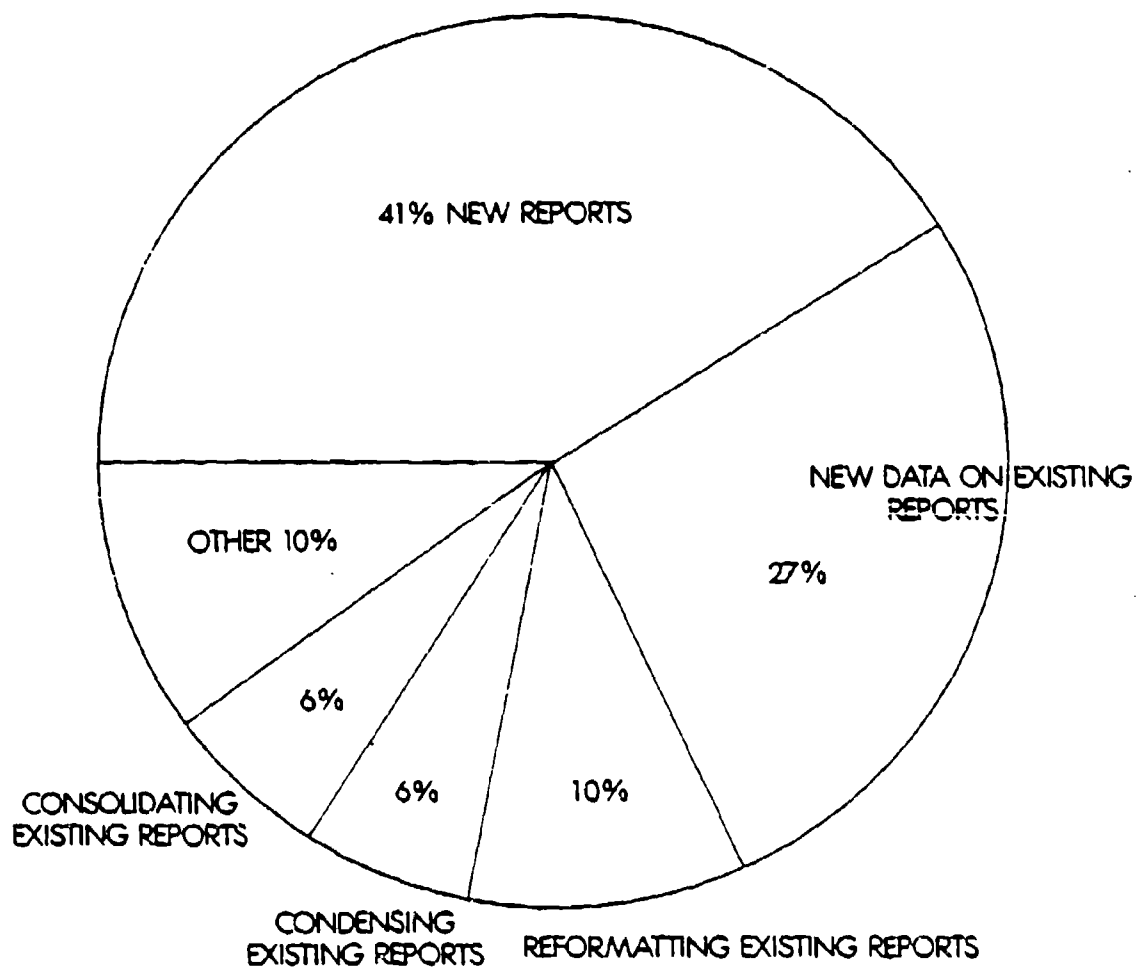
- System hardware and software reliability.
- Data integrity in application system.

TABLE 2
RESPONSIBILITY FOR MAINTENANCE AREAS

<u>AREA / ACTIVITY</u>	<u>USERS</u>	<u>SYSTEMS</u>	<u>OPERATIONS</u>
Production			
Data entry	X		X
Inquiry	X		
Production initiation			
Batch			X
On-line	X		
Fixing problems		X	
Enhancements			
Report generation	X		
Addition of new data elements	X		
Addition of new functions		X	
Modification of reports	X		
Modification of system tables		X	
Requirements analysis	X		
Design	X	X	X
Maintenance			
Recoding for efficiency		X	
Improving documentation	X	X	
Accommodate changes in hardware / software		X	X
Accommodate changes in files		X	
Accommodate changes in input data	X		
Management			
Monitoring of change requests	X	X	
Project control		X	
Cost accounting	X	X	

USER ENHANCEMENTS BY TYPE

(487 DPMA member organizations)



Data from:

Lientz, B.P., Swanson, E.B.

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Reading, MA: Addison-Wesley Publishing Company, 1980.

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